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Sustainable Capacity Expansion in Family-Owned Food Enterprises: Mechanisms for Reducing Harmful Emissions

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In response to global sustainability demands, this study aims to assess how family-owned food industry enterprises integrate emission reduction mechanisms into their capacity expansion strategies, with the goal of identifying key internal decision-making drivers and evaluating their environmental effectiveness. Family-owned food enterprises were chosen as they dominate the European agro-food sector and, through their long-term orientation and intergenerational responsibility, provide a unique context for aligning growth with sustainability. Energy usage and investment data from five such businesses were analysed over a three-year period. While energy data supported quantitative modelling of emission trends, the investment records—extracted from sustainability reports—were qualitatively assessed and coded according to their alignment with three internal decision-making drivers: socio-emotional wealth, intergenerational cooperation, and heterogeneous governance. Results reveal a consistent trend of investments in energy-efficient technologies, process optimisation, and renewable energy adoption. These efforts led to quantifiable reductions in emission intensity, with CO_2 intensity decreasing by 8.8 % and energy use per falling below OECD benchmarks (1.66 MWh/t). In parallel, production capacities increased by approximately 15 %, demonstrating that growth and environmental performance can be aligned. The findings demonstrate that long-term-oriented family firms are aligning growth with sustainability goals. This research contributes to sustainable industrial development literature by evidencing that environmental responsibility and production expansion can be pursued simultaneously.

1. Introduction

In the wake of escalating climate challenges and global decarbonisation goals, the food industry faces growing pressure to transition toward low-emission production systems (Sharma and Irving, 2005). Family-owned businesses—characterised by long-term strategic orientation, intergenerational responsibility, and often deeply rooted local identities—are uniquely positioned to contribute to this transformation (Chrisman et al., 2005).
While large multinational corporations have adopted advanced environmental reporting and Science-Based Targets (SBTs), the role of small and medium-sized enterprises (SMEs), particularly in the food sector, remains under-examined (Keller and Huszka, 2024). In Europe, family-owned agro-food firms constitute a significant portion of the supply chain, yet empirical evidence on their climate strategies is limited (Wildnerova et al., 2024).
The integration of environmental strategies within family-owned food enterprises has been gaining attention from scholars across multiple domains, particularly in the areas of sustainable packaging, emission decomposition analysis, and cross-sector benchmarking (Del Brío and Junquera, 2003).

1.1 Literature Review

In the context of climate change mitigation, there is increasing pressure on industrial actors—including those in the food sector—to align growth with sustainability goals. Family-owned enterprises, especially within the small and medium-sized segment, are playing an increasingly visible role in this transition. Their long-term orientation, intergenerational responsibility, and often deeply embedded local values offer both constraints and advantages when implementing emission-reduction strategies. This study integrates three strands of prior research: decomposition approaches, Logarithmic Mean Divisia Index (LMDI) for analysing emission drivers,

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benchmarking frameworks (OECD) for contextualising performance, and econometric models (CFGLS) for assessing cross-pollutant dynamics, while linking them to family business decision-making theories.

Existing literature highlights that while multinational corporations have adopted measurable emission targets and reporting schemes, such as SBTs, small family businesses are underrepresented in empirical sustainability studies. Recent analyses emphasise that in SMEs, including those in the food industry, the environmental agenda is often driven by internal values rather than external compliance (Nemes et al., 2025). As such, these businesses frequently undertake CO_2 or energy efficiency actions without necessarily formalising them in public sustainability strategies.

Quantitative methods for analysing industrial emissions have evolved significantly, with the LMDI gaining recognition as a preferred approach for decomposing CO_2 emission changes into production, intensity, and fuel mix components (Ang, 2005). Benchmarking data from the OECD (2017) provides useful reference ranges for energy intensity (2–4 MWh/t) and CO_2 intensity (0.22–0.28 t CO_2/MWh), based on average values across the entire agro-food and light manufacturing sectors, encompassing a wide variety of product types—from primary agricultural outputs to processed food and consumer goods, which can contextualize the performance of companies like Lipóti Pékség, Kométa, or Sofidel within broader industrial norms.

In addition to decomposition and benchmarking, econometric models—particularly Cross-sectional Feasible Generalised Least Squares (CFGLS)—have emerged as powerful tools to analyse how pollutant emissions correlate across firms. While most studies isolate CO_2 or NO_x, joint modelling reveals how strategies targeting one pollutant may deliver co-benefits or trade-offs (e.g., reduction in CO_2 also reduces NO_x emissions). These findings collectively point to a critical research gap: while the environmental behaviour of large corporations is increasingly well-documented, much less is known about how small, family-owned firms—particularly in the food sector—approach sustainability in the context of growth.

This study addresses that gap by assessing whether and how family-owned food enterprises in Central and Southern Europe are aligning capacity expansion with emission reduction. To this end, it integrates three methodological approaches: LMDI analysis to identify internal drivers of CO_2 emissions, OECD benchmarking to evaluate external performance in terms of energy and carbon intensity, and a CFGLS regression to explore the interrelationships among CO_2, NO_x, and energy use. By combining these tools, the research contributes to a nuanced understanding of sustainable industrial development within an often-overlooked segment of the European economy.

A meta-analysis of family firms by Lorenzen et al. (2024) suggests that while family-owned enterprises do not universally outperform non-family firms, they exhibit a lower environmental footprint, particularly in primary emissions such as CO_2 and NO_x. This suggests that long-term ownership and identity-related factors can foster environmentally responsible practices. Complementing this, German case studies show that sustainability initiatives are not merely compliance mandates; instead, they are integrated into firm strategies through innovation and proactive management—for instance, when family-controlled companies embed green technologies within their core operations (Becker et al., 2024). Specifically focusing on the food sector, Liu et al. (2023) provide a comprehensive overview of carbon mitigation strategies in the industry. Their findings reveal a convergence between technological innovation (e.g., heat recovery, electrification), certification frameworks (e.g., ISO 14001), and participation in carbon markets.

In the Central European context, Nemes et al. (2024b) developed and validated a decision-making model for capacity expansion in Hungarian family-owned food businesses. Their mixed-method research identified three critical internal factors influencing strategic decisions: socio-emotional wealth, intergenerational cooperation, and heterogeneous governance structures. These dimensions are especially relevant in this paper, which investigates how sustainability goals intersect with growth trajectories in similar organisational settings.

Together, these studies provide a multi-layered theoretical background. They offer not only empirical support for using energy-emission models such as LMDI and CFGLS but also validate the structural assumptions behind the research design: that internal cultural and governance dynamics play a pivotal role in how environmental strategies are implemented in family-owned SMEs.

These findings collectively point to a critical research gap: while the environmental behaviour of large corporations is increasingly well-documented, much less is known about how small, family-owned firms—particularly in the food sector—approach sustainability in the context of growth. This study addresses that gap by asking: How do internal decision-making factors influence the integration of emission reduction strategies into capacity expansion initiatives in family-owned food businesses?

2. Methods

This study adopts a mixed-method quantitative approach to examine how family-owned food enterprises in Hungary and Italy integrate emission reduction efforts into capacity expansion. The analysis follows three methodological steps: LMDI decomposition (applied to Lipóti Pékség, the only firm with complete three-year

(3 y) data), OECD benchmarking across all five companies, and CFGLS regression modelling to assess emission interrelationships. This structure balances depth and breadth within the sample constraints.

2.1 Data Sources and Company Selection

The firms were selected through purposive sampling, following the logic of analytic generalisation in case study research (Yin, 2014), ensuring both access to sustainability data and alignment with the theoretical framework of family business decision-making. While the sample ensures data availability and sectoral diversity, its limited size makes it analytically relevant but statistically unrepresentative of the broader family business landscape, highlighting the need for future studies with an expanded dataset. The selected companies are:

1. Lipóti Pékség Kft. (bakery and food retail, Hungary),
2. Kométa 99 Zrt. (meat processing, Hungary),
3. Sofidel S.p.A. (tissue and paper, Italy),
4. Davines S.p.A. (cosmetics and food-grade production inputs, Italy),
5. Fratelli Carli S.p.A. (olive oil and food distribution, Italy).

The rationale for choosing these five firms lies in their shared characteristics:

- They are family-owned or family-led enterprises, aligning with the research's focus on ownership influence on sustainability.
- They operate within energy- and emission-intensive production environments, making them suitable candidates for investigating CO_2 and NO_x dynamics.
- They represent a diverse mix of production types—from food processing to consumer goods manufacturing—allowing for comparative generalisation within the family-business ecosystem.
- All companies publish annual sustainability or energy audit reports, enabling the extraction of consistent input data for the LMDI and CFGLS models.

This selection also aligns conceptually with the model of internal decision-making factors in family businesses proposed by Nemes et al. (2025). According to their study, capacity expansion decisions in Hungarian food-sector family firms are shaped by three key internal elements:

- Socio-emotional wealth: the desire to preserve family legacy and reputation,
- Intergenerational cooperation: coordination and trust across management generations,
- Heterogeneous governance: decision-making structures that blend tradition with adaptive strategies.

Thus, the selected sample not only provides the necessary quantitative data for emissions analysis but also maps well onto the qualitative framework of family business behaviour, allowing this study to contribute to both empirical and conceptual discussions in the field.

Energy and emission data were obtained from company sustainability and energy audit reports; in the case of Sofidel and Davines, these reports are externally verified by third-party auditors, while for Lipóti and Kométa, the data derive from legally mandated energy audits prepared and disclosed in compliance with Hungarian regulations, without additional independent certification.

2.2 Measurements, values, and units

As a first component of the analysis proposed, the Logarithmic Mean Divisia Index (LMDI) method was employed to decompose year-on-year changes in CO_2 emissions into three factors: production volume, energy intensity, and emission factor. The decomposition equation used is:

$$\Delta C = \Delta C_{activity} + \Delta C_{intensity} + \Delta C_{emission} \quad (1)$$

where:

ΔC: total change in CO_2 emissions,

ΔC activity: change due to variation in the physical quantity of the final product produced (t),

ΔC intensity: change due to energy efficiency (MWh/t),

ΔC emission: change due to emission factors (t CO_2/MWh).

This analysis was conducted for Lipóti Pékség Kft., with 3 y of consecutive data (2021–2023) derived from energy audit reports.

As a second component of the analysis, energy and emissions data from all five companies were compared against OECD performance standards for the agro-food industry, specifically:

- Energy intensity: 2.0–4.0 MWh/t
- CO_2 emissions per MWh: 0.22–0.28 t CO_2/MWh

This comparison highlights relative efficiency and carbon performance at the firm level, enabling external validation of operational sustainability.

The third component of the analysis explores inter-company variation in emission behaviour via a CFGLS regression. The model regresses NO_x emissions on CO_2 emissions and total energy use. Since CO_2 is typically derived from energy consumption, the two predictors may be collinear. Although both were retained to explore their distinct roles, this introduces potential multicollinearity, which may affect the reliability of individual coefficients. Future research should apply diagnostic tests or alternative specifications to confirm model robustness.

$$NO_i = \alpha + \beta_1 CO_i + \beta_2 \text{Energy} + \epsilon_i \quad (2)$$

This model controls for firm size and heterogeneity, providing insight into the co-movement of greenhouse gases across companies with different operational profiles.

Beyond quantitative modelling, the study integrates a qualitative layer of analysis by mapping capacity expansion activities reported in the companies' sustainability disclosures against the internal decision-making model proposed by Nemes et al. (2024b). This model identifies three internal drivers – socio-emotional wealth, intergenerational cooperation, and heterogeneous governance – as pivotal in shaping strategic choices in family-owned food enterprises.

To apply this framework, reported investments (e.g., new production lines, technological upgrades, renewable energy projects) were coded according to which of these internal factors they most likely reflect. For example, infrastructure expansions tied to brand legacy or community visibility were linked to socio-emotional wealth, while initiatives explicitly endorsed by multi-generational leadership teams were mapped to intergenerational cooperation. Investments demonstrating hybrid governance or professionalised management practices (e.g., sustainability KPIs, third-party certifications) were associated with heterogeneous governance.

This triangulation allows for a richer interpretation of the emission-related findings and provides a bridge between organisational psychology and environmental performance, offering an innovative way to validate theoretical constructs using real-world data.

3. Result and discussion

The LMDI analysis conducted on Lipóti Pékség's operational data from 2021 to 2023 (Table 1) reveals that the total CO_2 emissions increased from approximately 1.599 t to 1.700 t. This change was decomposed into three main drivers:

- A +15 % increase in production volume (activity effect),
- An 8.8 % reduction in energy intensity (efficiency effect),
- A neutral emission factor, as the energy mix remained largely unchanged (electricity and natural gas).

Table 1: Decomposition of CO_2 Emissions: The Case of Lipóti Pékség

Year	CO_2 Emissions (t)	Energy Use (MWh)	Production (t)	CO_2 / MWh (t/MWh)	Energy Intensity (MWh/t)
2021	1.599	~6,000	~3,300	0.266	1.82
2022	1.65	~6,200	~3,500	0.266	1.77
2023	1.7	~6,300	~3,800	0.270	1.66

This efficiency effect suggests that the firm enhanced its internal processes—such as equipment upgrades, waste heat recovery, or improved production scheduling—to produce more output per unit of energy. This form of strategic energy reduction aligns closely with family business values: rather than pursuing quick returns through fuel switching, the company invested in sustainable efficiency improvements that preserve long-term competitiveness and community reputation. Such behaviour reflects the socio-emotional wealth motive, where energy-conscious decisions are deeply embedded in the firm's identity and commitment to legacy. The results indicate that while capacity expansion led to higher absolute emissions, internal efficiency gains partially offset this growth. From a strategic perspective, these efficiency improvements may reflect both economic incentives (e.g., reduced operating costs) and deeper family-business motives. In line with the socio-emotional wealth framework proposed by Nemes et al. (2025), the choice to invest in visible, process-based energy upgrades—rather than low-cost or low-profile alternatives—suggests a parallel intent to reinforce the firm's local reputation and preserve long-term family legacy. When assessed against OECD benchmarks for the agro-food industry (energy intensity: 2–4 MWh/t, CO_2 intensity: 0.22–0.28 t/MWh), Table 2 shows that the selected firms displayed varying levels of sustainability performance:

- Lipóti Pékség outperformed the benchmark with an energy intensity of 1.66 MWh/t and a CO_2 intensity of 0.27 t/MWh.

- Kométa fell within the benchmark range on energy use (2.33 MWh/t) but slightly exceeded the carbon intensity threshold (0.30 t/MWh).
- Sofidel exhibited high absolute energy use (95,000 MWh/y), typical for paper manufacturing, and was above the CO_2 benchmark (0.31 t/MWh).
- Davines (0.22 t CO_2/MWh) and Fratelli Carli (0.25 t CO_2/MWh) both fell within OECD CO_2 benchmarks, largely due to their use of certified renewable energy. However, their energy intensity (MWh/t) was not disclosed, limiting full comparability.

These comparisons suggest that operational scale and industry type strongly influence emission efficiency. However, the adoption of cleaner energy sources—especially by Italian firms—indicates proactive governance strategies. The adoption of cleaner energy sources—particularly by the Italian firms—can be interpreted as evidence of proactive governance strategies, as reflected in their structured sustainability disclosures and formalised energy procurement practices. However, such decisions may also align with socio-emotional wealth motives, including legacy building and brand reputation, especially in family businesses with strong public identities. This supports the “heterogeneous governance” component of the model by Nemes et al (2024b) model, where modern management practices coexist with family ownership to drive sustainability.

Table 2: Benchmarking Against OECD Performance Standards

Company	Energy Intensity (MWh/t)	CO_2 Intensity (t/MWh)	Meets OECD?	
			Energy	CO_2
Lipóti	1.66	0.27	yes	yes
Kométa	2.33	0.30	yes	no
Sofidel	3.80	0.29	yes	no
Davines	–	0.22	no	yes
Fratelli Carli	–	0.25	-	yes

The CFGLS model was estimated across the five firms using NO_x emissions as the dependent variable, with CO_2 emissions and total energy consumption as independent variables. A standard t-test for regression coefficients was used to assess statistical significance. The results revealed a statistically significant positive relationship between CO_2 and NO_x emissions ($\beta_1 \approx 0.0024$, $p < 0.05$), while the effect of energy consumption was positive but not significant ($\beta_2 \approx 0.00007$, $p > 0.10$).

These results suggest that:

- CO_2 emissions can serve as a proxy indicator for NO_x trends in emission monitoring,
- Companies that invest in CO_2 mitigation technologies may reap co-benefits in air pollutant reduction,
- The relationship is more pronounced in firms with homogeneous fuel profiles (e.g., Kométa and Lipóti).

Table 3: CFGLS Regression: Cross-Pollutant Dynamics

Company	CO_2 Emissions (t)	Energy Use (MWh)	NO_x Emissions (t, estimated)
Lipóti	1 700	6 300	6
Kométa	4 200	14 000	11
Sofidel	25 000	95 000	55
Davines	1 000	4 000	4
Fratelli Carli	1 300	5 000	5

From a governance standpoint, these findings reinforce the relevance of intergenerational cooperation in strategic alignment: firms with clear sustainability visions and generational dialogue (e.g., Kométa) were more likely to invest in technologies with dual benefits.

Bringing together the three analytical layers, the study provides a holistic view of how family firms balance growth ambitions with environmental responsibility. Lipóti’s efficiency-driven growth, Kométa’s steam system retrofit, and Sofidel’s large-scale renewable investment each reflect different manifestations of the internal decision factors proposed by Nemes et al. (2025).

- Socio-emotional wealth guided community-facing energy actions.
- Intergenerational cooperation supported capital-intensive upgrades.
- Heterogeneous governance enabled the professionalisation of environmental strategies.

4. Conclusions

This study examined how internal decision-making factors influence the integration of emission reduction strategies into capacity expansion among family-owned food firms in Hungary and Italy. Using LMDI, OECD benchmarking, and CFGLS regression, the analysis revealed that while production growth drives emissions, efficiency improvements and renewable investments could offset this trend.

Importantly, the results aligned with the internal factor model of Nemes et al. (2024b): firms driven by socio-emotional wealth focused on community-visible energy projects; intergenerational cooperation supported modernisation; and heterogeneous governance enabled strategic sustainability planning. These findings confirm that internal decision structures significantly shape how environmental goals are embedded into operational growth. Future research should expand the sample and explore how these internal factors evolve alongside market and policy pressures.

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